(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 510 849 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 92303270.0

(22) Date of filing: 13.04.92

(51) Int. Cl.[5]: B03C 1/28, B03C 1/025

(30) Priority: 25.04.91 GB 9108976

(43) Date of publication of application: 28.10.92 Bulletin 92/44

(84) Designated Contracting States: AT BE CH DE FR IT LI NL SE

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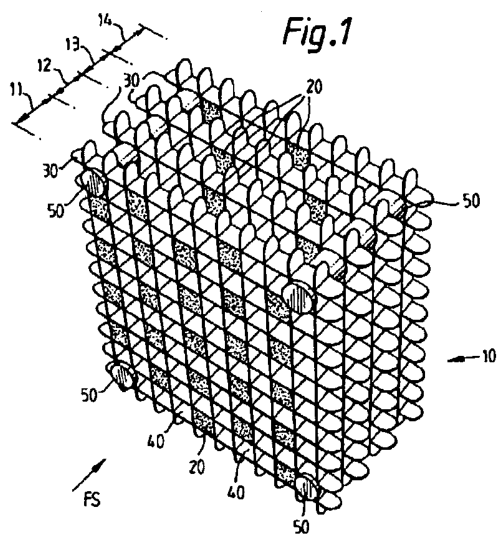
(54) Magnetic separators.

(57) A filter (10) for removing magnetic particles from a fluid stream comprises successive sub-sections (11-14) along the length of the filter each having a distributed pattern of permanent magnet particle collectors (20) and fluid flow apertures (40), this pattern being different in the sub-sections such that the collectors of the successive sub-sections together cover the whole cross-section area of the filter and such that the apertures of the successive sub-sections together define meandering fluid flow paths through the filter.

Fig.1



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The present invention relates to magnetic separators, that is to filters for removing magnetic particles from a fluid stream. The magnetic particles may be mixed in the fluid with non-magnetic particles.

Magnetic separation, like many other forms of physical separation, is based upon competition between the magnetic force and other forces acting on the magnetic particles. Such other forces may include the forces of inertia, gravitation and drag forces of fluid viscosity. The magnetic force pulls the magnetic particles, which are ferromagnetic, antiferromagnetic, ferrimagnetic and paramagnetic in type, in one direction whereas the other forces pull the magnetic particles and any non-magnetic, i.e. diamagnetic, particles in another direction. In the case of known high intensity magnetic separator filters and, more recently, high gradient magnetic separator filters, the magnetic particles are pulled towards and eventually captured on magnetic particle collectors whereas any non-magnetic particles and the fluid pass through the filter. The consequence is that the magnetic particles are removed from the fluid-particle mixture and thus separated from the non-magnetic particle species. The quality of separation depends upon the relative strength of the competing forces. The larger the magnetic force, the stronger the extraction of magnetic particles from the fluid and hence the larger their deposition on the magnetic collectors of the separator.

The magnetic force acting upon a particle is given as

$$\vec{F}_m = \chi V_p \text{ grad } (\tfrac{1}{2} H B_0),$$

where H and $B_o = \mu_o H$ are, respectively, the magnitudes of the magnetic field and the magnetic flux density at the particle position, V_p is the particle volume, χ is the difference between the volume susceptibilities of the particle and the fluid and $\mu_o = 4 \times 10^{-7} Hm^{-1}$ is the permeability of free space.

The expression for $\vec{F}_m$ is a product of two factors: the first factor, χV_p, reflects the physical properties of the particle, whereas the second factor, the magnetic force density

$$\vec{f}_m = \text{grad}(\tfrac{1}{2} H B_0),$$

reflects the separator extraction capability at the particle position. In a special case of isodynamic separators $\vec{f}_m$ is constant, i.e. position - independent, over the whole zone in which the separation takes place. In other cases $\vec{f}_m$ varies from place to place throughout the separation zone. However, it is always possible to establish a typical value of the magnetic force density which can be attributed to the separator as a whole and as such will characterize it as far as its extraction capability is concerned.

Consequently, in the design of many known high intensity or high gradient magnetic separators a considerable effort is spent to attain large values of $\vec{f}_m$. This is achieved by employing strong superconducting or conventional magnets to generate high magnetic fields which are used to magnetize particle collectors, of relatively small dimensions, produced from a low coercivity "soft" magnetic material. Thus not only the magnetic fields but also their gradients are high and hence large values of $\vec{f}_m$ are obtained. This leads to high extraction capabilities and efficiences, which are the main advantages of magnetic separators constructed in this way. However, there are also disadvantages, such as e.g. the considerable construction and running costs of the superconducting or conventional magnets that are needed for generating high magnetic fields over large separation zone volumes which are used in industrial applications. If these machines are used as filters then there is another disadvantage associated with the fact that should power failure occur all the magnetic particulate mass, captured during the last separator duty cycle, would be released back into the flow circuit of the industrial plant.

If particle collectors, instead of being produced from a low coercivity "soft" magnetic material, are produced from a high coercivity magnetically "hard" magnetic material as permanently magnetized collecting elements, then the high costs and other difficulties, arising from providing and powering the magnets for generating external magnetic fields, are avoided. Examples of such a magnetic material are alnico, hexagonal ferrites, RCo_5, $Sm_2(TM)_{17}$ and $R_2 Fe_{14} B$ compounds.

The separator filter efficiency, that is the ratio of magnetic particles captured to particles entering the filter in a unit of time, is dependent on the capture cross-sections of the particle collectors when magnetised, which depends upon the operational parameters of the separation system, particularly upon the magnetic to fluid velocity ratio V_m/V_o, where $V_m = 2\mu_o \chi M^2 b^2/(9\eta a)$ is the magnetic velocity, M and a are, respectively, the magnetization and effective radius of a collector, b is the particle radius, η and V_o are, respectively, the viscosity and velocity of the particle carrying fluid, and other symbols have already been defined. The magnetization, magnetic strength, of permanently magnetized particle collectors made of "hard" magnetic material is inherently less than the magnetization which can be achieved with particle col-

lectors made of "soft" magnetic material employing an external magnetic field. Thus, if permanently magnetized particle collectors are used, there is an inherent disadvantage of lower capture cross-sections of the particle collectors and in consequence a lower normalised capture cross-section and lower value of $\vec{f}_m$, the magnetic force density mentioned above, for a separator filter. Another inherent disadvantage of using permanently magnetized particle collectors is the difficulty in eventually cleaning the filter by removing the particles from the permanently magnetized collectors compared with the case where the particle collectors are of "soft" magnetic material. The extent of the cleaning problem depends on the frequency with which this needs to be performed which in turn depends on the retention capacity of the filter.

An object of the present invention is to provide a filter using permanently magnetized collectors in which the disadvantages just mentioned are to a large extent overcome.

The basic idea of the invention lies in a spatial arrangement of the permanently magnetized collectors in distributed patterns which vary over a length of the filter so as to maximise the probability of capture of magnetic particles within that length of the filter while providing a satisfactory retention capacity over that length.

According to the invention there is provided a filter for removing magnetic particles from a fluid stream, the filter comprising a cage structure of predetermined length parallel to the fluid stream and predetermined cross-section area, in which a cage section occupies at least part of said length and the whole of said cross-section area and comprises successive cage sub-sections each occupying the whole of said cross-section area, in which each cage sub-section comprises permanently magnetized particle collectors and spacing means which locate said collectors in a distributed pattern of particle collectors and fluid flow apertures, and in which said distributed pattern of collectors and apertures is different in said successive sub-sections such that the collectors of said successive sub-sections together cover substantially the whole of said cross-section area and such that the apertures of said successive sub-sections together define meandering fluid flow paths through the cage section.

We have devised two arrangements for providing the distributed patterns of collectors and fluid flow apertures in a cage structure as just described, that is to say an ordered arrangement and a random arrangement.

In the ordered arrangement, the spacing means in each cage sub-section comprises a grid structure occupying substantially the whole of said cross-section area and part of the length of said sub-section such that successive said grid structures are spaced apart along the length of said cage section, and the grid structures determine that said distributed pattern of collectors and apertures in each sub-section is an ordered array.

In the random arrangement, said cage section has an inlet screen, an outlet screen and an outer wall providing a single continuous volume holding said collectors, each collector is provided with an individual spacer, the spacers together providing said spacing means, and the collectors are randomly arranged in said continuous volume of the cage section such that the cage sub-sections are notional and contiguous and such that the collectors and their spacers overlap from one sub-section to another.

In both the ordered arrangement and the random arrangement, the distribution of particle collectors over the cage section is such that over the length of that section there is a high probability that each magnetic particle in the fluid stream will meet a particle collector face and be captured. In fact we have found that nearly the same separation efficiency can be obtained by approximately the same number of particle collectors in either the ordered or the random arrangement. At the same time, in both the ordered and the random arrangements, the meandering fluid flow paths provided through the cage section enable the fluid to flow freely through that section. We have also found that after a substantial time of use of filters having either of these arrangements a high proportion of magnetic particles collected are collected in the first sub-section, or first respective notional sub-section, so that the filters may be used for a considerable further time before their retention capacity is used up and they need to be cleaned. The already high separation efficiency and retention capacity achieved by a single cage section can be increased by including one or more further such cage sections in the filter while still allowing the fluid to flow freely through the filter.

An advantage of the ordered arrangement with spaced grid structures compared with the random arrangement is that it is easier to provide a filter of long length if required by simply providing enough grid structures. An advantage of the random arrangement compared with the ordered arrangement is that is is easier to provide a filter of irregular cross-section if required by simply providing an outer wall for the cage section of the appropriate shape and filling the single continuous volume with the collectors having their individual spacers.

A filter according to the invention will be required to allow a particular throughput of fluid (volume per second). A particular large or small cross-section may be available to accommodate a filter for that fluid throughput or it may be possible

to choose the cross-section of the filter cage to be larger or smaller. The fluid throughput, the filter cross-section area and the fraction of that cross-section area in each cage sub-section which provides fluid flow apertures together determine the fluid velocity through the filter and hence the drag forces of the fluid which will pull magnetic particles away from the collectors. These drag forces must be overcome by the magnetic strength with which the magnetic particles are attracted by the collectors. Comparatively strong or weak permanently magnetized magnetic particle collectors, using higher or lower coercivity magnetically "hard" magnetic materials, may be used in a filter according to the invention. If a constraint on the size of the filter cross-section determines a certain high fluid velocity then the collectors must be chosen to have sufficient magnetic strength to capture the magnetic particles. If it is possible to choose a comparatively large filter cross-section and thereby reduce the fluid velocity then comparatively weak magnetic strength particle collectors may be used. Also for a given filter cross-section the fluid velocity may be reduced by having a smaller fraction of the filter cross-section area for each sub-section occupied by particle collectors (a smaller "packing fraction") and hence a higher fraction of that cross-section area providing fluid flow apertures. Such a smaller packing fraction in each cage sub-section will require more sub-sections and hence a greater length for the cage section in which the collectors of the successive sub-sections together cover substantially the whole of the cage cross-section area.

Given a certain fluid velocity and a certain magnetic strength of the collectors, other factors can be varied to maximise the separation efficiency. One factor is that for a given "packing fraction" in each sub-section the magnetic particle capture efficiency is greater if the size of the individual collectors is smaller, and this can be made use of if the cost of providing a correspondingly larger number of collectors is acceptable. Another factor is that, in the case of the ordered arrangement, the spacing of successive grid structures along the length of the cage section may be varied. The grid structures must not be so far apart that the effect of the collectors acting together to cover the whole cage cross-section area is lost, and the grid structures must not be so close together that meandering fluid flow paths are not effectively provided. The actual meandering fluid velocity is higher than the average fluid velocity through the filter and this meandering velocity is increased as the grid structures are put closer together. If the magnetic strength of the collectors is higher then this increased fluid velocity due to closer grid structures can be accommodated and a higher separation efficiency may be achieved.

If for a certain fluid velocity and a certain magnetic strength of collectors, magnetic particles are captured but the separation efficiency of a single cage section is not as high as is required for the filter then the filter may be provided with one or more further cage sections to bring the filter efficiency up to the required level.

The ordered arrangement may be such that each grid structure provides an ordered array of holes, such that the collectors of each sub-section each occupy one of said holes, and such that the fluid flow apertures of each sub-section are each provided by a said hole not occupied by a collector. In this case the collectors may be held to the respective grid structures with fasteners. Alternatively in this case the grid structures may be formed of plastics material and the collectors may be solid permanent magnets impressed or moulded into the grid structures, and this configuration may be more suitable for large scale production. Also for the ordered arrangement, screens may be provided between the grid structures, said screens being formed of magnetic material which is magnetisable by the permanently magnetised collectors. These screens will tend to be efficient in capturing comparatively small magnetic particles from the fluid flow on the edges of their mesh while comparatively large magnetic particles pass through for capture on the collectors of the grid structures. This extra capture of magnetic particles by the screens increases the overall separation efficiency and retention capacity of the filter. The cage section may also have an inlet screen and an outlet screen each formed of magnetic material which is magnetisable by the permanently magnetised collectors. These magnetisable inlet and outlet screens will further improve the filter efficiency and capacity while at the same time performing the function of keeping large particle debris out of the filter.

In the random arrangement, the inlet screen and outlet screen may be formed of magnetic material which is magnetisable by the permanently magnetised collectors. Again, this will increase the overall separation efficiency and retention capacity for the filter.

A filter in accordance with the invention may be incorporated in various cleaning installations. Examples are an installation for cleaning steam condensor waters in power stations, an installation for the cleaning of process and waste waters or other fluids in steel mills, chemical, pharmaceutical and nuclear plants, and an installation for the cleaning of air, smoke or any gas-particle mixture in steel mills, chemical pharmaceutical, nuclear and asbestos plants.

Embodiments of the present invention will now be described, by way of example, with reference to

the accompanying drawings, in which:-

Figure 1 shows a schematic front perspective view of an ordered arrangement cage section of a magnetic separator filter comprising four successive cage sub-sections,

Figure 2 shows a top view of the cage section of Figure 1 in which spaced apart grid structures, one in each cage sub-section, are more clearly seen,

Figures 3A to 3D show a front view of each of the four grid structures, illustrating a distributed pattern of magnetic particle collectors and fluid flow apertures which is different in the four grid structures,

Figures 4A and 4B show two possible shapes for the magnetic particle collectors,

Figure 5 shows a clip for fastening a magnetic particle collector in a hole in one of the grid structures,

Figure 6 shows a top view of the cage section as in Figure 2, with the addition of magnetic material screens between the grid structure, a magnetic material inlet screen and a magnetic material outlet screen,

Figure 7 shows a top view of a random arrangement cage section of a magnetic separator filter, and

Figures 8A, 8B and 8C respectively show a split disc which is part of a spacer for a magnetic particle collector in the random arrangement of Figure 7, the split disc located on a particle collector, and two such split discs together providing a spacer on a particle collector.

Referring now to Figures 1 to 6, a filter for removing magnetic particles from a fluid stream comprises a cage structure of predetermined length parallel to the fluid stream, shown by the arrow FS, and predetermined cross-section area. The cage structure has a cage section 10 as shown in Figures 1, 2 and 6 which occupies the whole cross-section area of the filter and at least part of its length, that is to say that the cage section 10 shown may be repeated along the length of the filter. The cage section 10 comprises four successive cage sub-sections 11, 12, 13 and 14 each occupying the whole of the cage structure cross-section area. Each cage sub-section 11-14 comprises permanently magnetized particle collectors 20 and spacing means which locate the collectors 20 in a distributed pattern of particle collectors and fluid flow apertures. The spacing means in each cage sub-section comprises a grid structure 30 occupying substantially the whole of the cross-section area and part of the length of that sub-section such that successive grid structures 30 are spaced apart along the length of the cage section. Each grid structure 30 is formed of plastics material providing an ordered array of holes 40, the collectors 20 of each sub-section each occupy one of these holes and the fluid flow apertures are each provided by one of these holes not occupied by a collector 20. Each grid structure 30 has a ten by ten array of these holes 40 four of which are occupied by supporting rods 50, twenty four of which are occupied by collectors 20 and seventy two of which provide a fluid flow aperture. Figures 3A-3D show the distributed pattern of collectors 20 and fluid flow apertures which is different in the four successive grid structures 30. The same group of four holes is referenced in each of Figures 3A to 3D with a particle collector 20A, 20B, 20C, 20D respectively occupying a different one of the four holes, the other three holes 40 being left as fluid flow apertures. With these patterns of the collectors 20A-20D repeated over the whole cross-section, the collectors 20 of the four successive grid structures together cover substantially the whole of the cage section cross-section area and the apertures provided by the unoccupied holes 40 of the four successive grid structures together define meandering fluid flow paths 41 through the cage section. The arrangement thus provides a high probability that each magnetic particle in the fluid stream will meet the face of a particle collector 20 and be captured in the cage section 10, while at the same time the paths 41 enable the fluid to flow freely through the cage section 10.

In an experimental cage structure of four grids 30, the holes 40 were rectangular as shown in the drawings and the particle collectors 20 were approximately 1 cm cubes as shown in Figure 4A of permanently magnetized Sm-Co alloy held to the grids 30 with fasteners 21 having the folded wing-clip shape as shown in Figure 5. An alternative collector shape 20A in which the cube is provided with ledges is shown in Figure 4B. Another experimental cage structure having eight grids 30, that is to say a second cage section 10 repeating the same particle collector distribution as a first cage section 10, with the particle collectors instead being of permanently magnetized barium hexaferrite material was found to have approximately the same separation efficiency, that is the ratio of magnetic particles captured to particles entering the filter in a unit of time, as the four grid filter with Sm-Co collectors.

We have found that after a substantial time of use of a cage structure filter as described above a high proportion of magnetic particles collected are collected in the first sub-section 11 of a cage section 10, so that the filter may be used for a considerable further time before its retention capacity would be used up and it would need to be cleaned. Cleaning may be effected by using high pressure fluid jets and or mechanical scrubbers in the free spaces between the grids 30.

Figure 6 shows the possible use of screens 60, between the grid structures 30, formed of magnetic material which is magnetisable by the permanently magnetised collectors 20. These screens 60 will, by improving the capture of comparatively small magnetic particles, reinforce the separation efficiency and retention capacity of the filter. Also shown are an inlet screen 61 and outlet screen 62, similarly magnetisable as the screen 60, which may further improve the filter efficiency and capacity while at the same time performing the function of keeping large particle debris out of the filter.

Possible variations of the ordered cage structure as described above are as follows. The holes in the grid structures could be shaped to hold other than cubic particle collectors, for example circular cylindrical shaped particle collectors. Instead of using fasteners to hold the collectors to the grids, the collectors could be solid permanent magnets impressed or moulded into the plastics material grids. Another possibility is to form the collectors as polymer bonded composite magnets in a moulding process together with the respective grid structures. Yet another possibility is that the collectors may be polymer bonded composite magnets formed by the grid structures. In all these variations the principle is retained that the grid structures determine that the distributed pattern of collectors and fluid flow apertures in each cage sub-section is an ordered array.

For a given value of the magnetic to fluid velocity ratio, which depends on a certain magnetic strength of the collectors and a certain fluid velocity, the collector sizes, the spacing between the collectors in each grid and the spacing between the grids can be varied and chosen to maximize the separation efficiency and retention capacity of the filter. These factors have been referred to in some detail in the discussion part of this specification preceding the description with reference to the drawings.

Referring now to Figures 7 and 8, another filter is shown, for removing magnetic particles from a fluid stream, comprising a cage structure of predetermined length parallel to the fluid stream, shown by the arrow FS, and a predetermined cross-section area. The cage structure has a cage section 100 which occupies the whole cross-section area of the filter and its length. A longer cage structure may be provided by extending its length to effectively repeat the cage section 100. The cage section 100 has an inlet screen 610 an outlet screen 620 and an outer wall 70 providing a single continuous volume holding permanently magnetized particle collectors 200 each provided with an individual spacer 80. The spacers 80 together provide spacing means for a random arrangement of the collectors 200 in the continuous volume of the cage section 100. The arrangement is such that the cage section 100 has notional and contiguous successive cage sub-sections 110, 120, 130, 140 in which each cage sub-section has a distributed pattern of collectors 200 and fluid flow apertures 401 with a different such pattern in the successive sub-sections, the collectors 200 and their spacers 80 overlapping from one sub-section 110-140 to another. As in the ordered arrangement previously described with reference to Figures 1 to 6, this random arrangement again is such that the collectors 200 of the four notional successive cage sub-sections 110-140 together cover substantially the whole of the cage section cross-section area and the apertures 401 together define meandering fluid flow paths 410 through the cage section. This arrangement thus again provides a high probability that each magnetic particle in the fluid stream will meet the face of a particle collector 200 and be captured in the cage section 100, while at the same time the paths 410 enable the fluid to flow freely through the cage section 100.

Experimental cage structures 100 as shown in Figure 7 have been made with particle collectors 200 being approximately 1cm cubes of permanently magnetized Sm-Co alloy or barium hexaferrite material. One form of spacer 80 is shown in Figures 8A to 8C. A non-magnetic aluminium disc 810 has a central rectangular hole 811 and a radial slit 812. The disc 810 Is bent to fit it over a cubic collector 200 and then a second similar disc 820 is bent to fit over the cube 200 and disc 810 at right angles to the disc 810. A filter as just described having ninety six randomly arranged collectors 200 of the same size and material as the collectors 20 used in the ordered arrangement filter shown in Figures 1 to 6 has been found to have nearly the same separation efficiency as that ordered arrangement filter.

The inlet screen 610 and the outlet screen 620 can be formed of magnetic material which is magnetisable by the permanently magnetized collectors 200. As in the case of the ordered arrangement, this reinforces the separation efficiency and retention capacity of the filter.

The collectors 200 and their spacers 80 could be varied from the form just described, as follows. The spacers 80 could be of magnetic material, and could for example be provided as integral extensions of the collectors 200 which could be of a shape other than cubic.

For a given value of the magnetic to fluid velocity ratio, which depends on a certain strength of the collectors and a certain fluid velocity, the collector sizes and the spacer sizes can be varied and chosen to maximise the separation efficiency and retention capacity of the random arrangement filter.

As has been referred to in some detail in the discussion part of this specification preceding the description with reference to the drawings, for both an ordered arrangement filter and the random arrangement filter, the filter will be required to allow a particular throughput of fluid. To ensure capture of the magnetic particles in that throughput, higher or lower magnetic strength collectors may be used, if allowed the cross-section area of the filter may be varied, the fraction of the cross-section area of each cage sub-section occupied by collectors may be varied and the length of the cage section may be varied.

Possible industrial installations in which a filter according to the invention may be incorporated have been mentioned in this specification immediately preceding the description with respect to the drawings.

Claims

1. A filter for removing magnetic particles from a fluid stream, the filter comprising a cage structure of predetermined length parallel to the fluid stream and predetermined cross-section area, in which a cage section occupies at least part of said length and the whole of said cross-section area and comprises successive cage sub-sections each occupying the whole of said cross-section area, in which each cage sub-section comprises permanently magnetised particle collectors and spacing means which locate said collectors in a distributed pattern of particle collectors and fluid flow apertures, and in which said distributed pattern of collectors and apertures is different in said successive sub-sections such that the collectors of said successive sub-sections together cover substantially the whole of said cross-section area and such that the apertures of said successive sub-sections together define meandering fluid flow paths through the cage section.

2. A filter as claimed in Claim 1, in which the spacing means in each cage sub-section comprise a grid structure occupying substantially the whole of said cross-section area and part of the length of said sub-section such that successive said grid structures are spaced apart along the length of said cage section, and in which the grid structures determine that said distributed pattern of collectors and apertures in each sub-section is an ordered array.

3. A filter as claimed in Claim 2, in which the collectors are polymer bonded composite magnets formed by the grid structures.

4. A filter as claimed In Claim 2, in which each grid structure provides an ordered array of holes, in which the collectors of each sub-section each occupy one of said holes, and in which the fluid flow apertures of each sub-section are each provided by a said hole not occupied by a collector.

5. A filter as claimed in Claim 4, in which the collectors of each sub-section are polymer bonded composite magnets formed in a moulding process together with the respective grid structure.

6. A filter as claimed in Claim 4, in which the grid structures are formed of plastics material and the collectors are solid permanent magnets impressed or moulded into the grid structures.

7. A filter as claimed in Claim 4, in which the collectors are held to the respective grid structures with fasteners.

8. A filter as claimed in any one of Claims 2 to 7, in which screens are provided between the grid structures, said screens being formed of magnetic material which is magnetisable by the permanently magnetised collectors.

9. A filter as claimed in any one of Claims 2 to 8, in which said cage section has an inlet screen and an outlet screen each formed of magnetic material which is magnetisable by the permanently magnetised collectors.

10. A filter as claimed in Claim 1, in which said cage section has an inlet screen, an outlet screen and an outer wall providing a single continuous volume holding said collectors, in which each collector is provided with an individual spacer, the spacers together providing said spacing means, and in which the collectors are randomly arranged in said continuous volume of the cage section such that the cage sub-sections are notional and contiguous and such that the collectors and their spacers overlap from one sub-section to another.

11. A filter as claimed in Claim 10, in which said spacers are non-magnetic.

12. A filter as claimed in Claim 10 or Claim 11, in which said inlet screen and outlet screen are formed of magnetic material which is magnetisable by the permanently magnetised collectors.

13. An installation for cleaning steam condensor

waters in power stations incorporating a filter in accordance with any preceding claim.

14. An installation for the cleaning of process and waste waters or other fluids in steel mills, chemical, pharmaceutical and nuclear plants incorporating a filter in accordance with any preceding claim.

15. An installation for the cleaning of air, smoke or any gas-particle mixture in steel mills, chemical pharmaceutical, nuclear and asbestos plants incorporating a filter in accordance with any preceding claim.

Fig.1

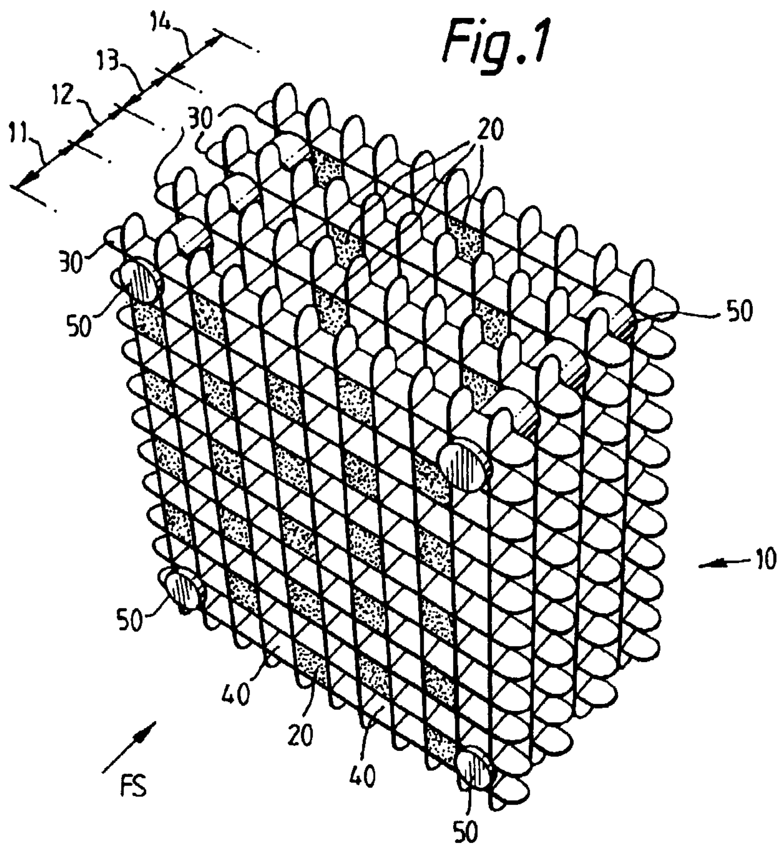
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Fig.2

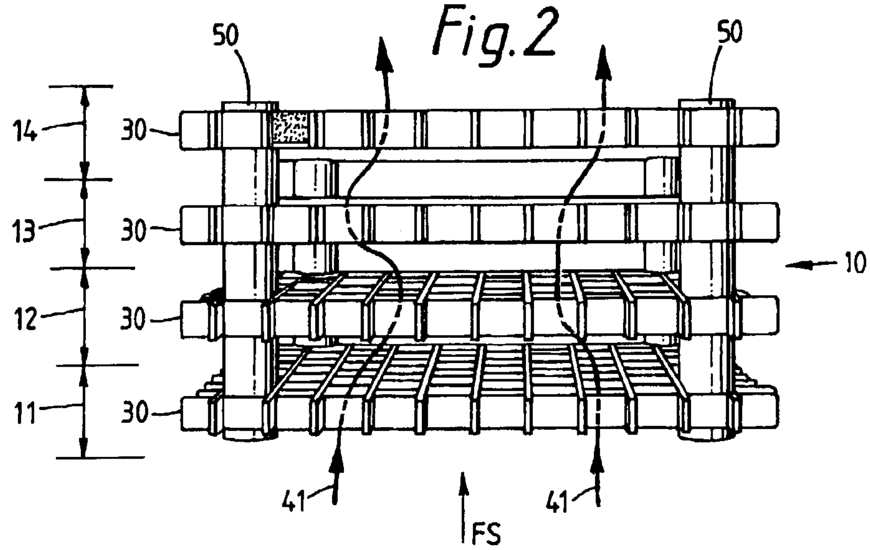
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Fig.3A

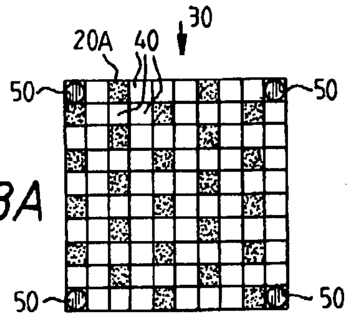

Fig.3B

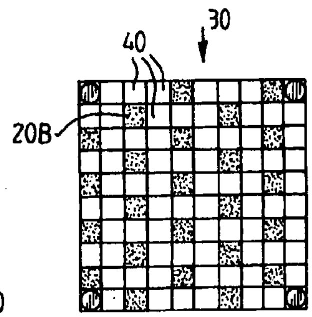

Fig.3C

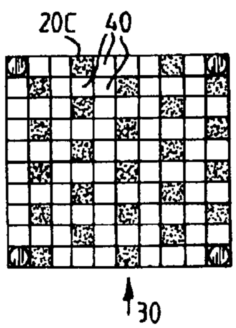

Fig.3D

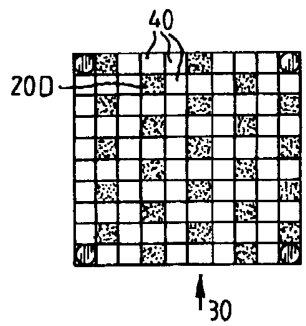

Fig.4A

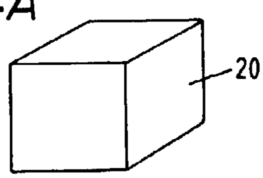

Fig.4B

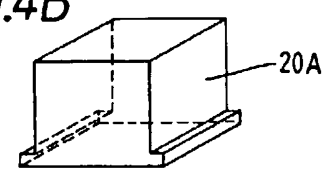

Fig.5

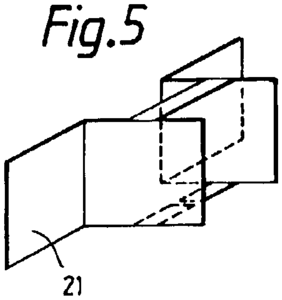

Fig.6

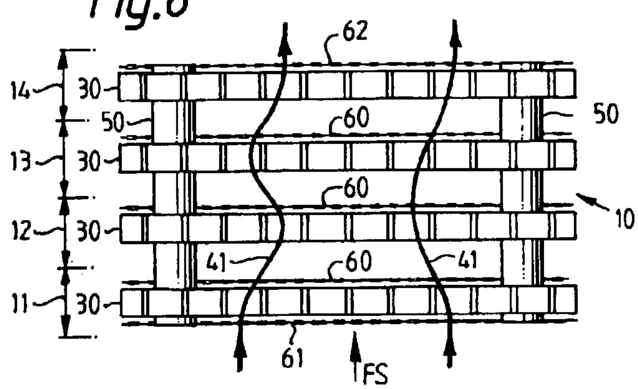

Fig.7

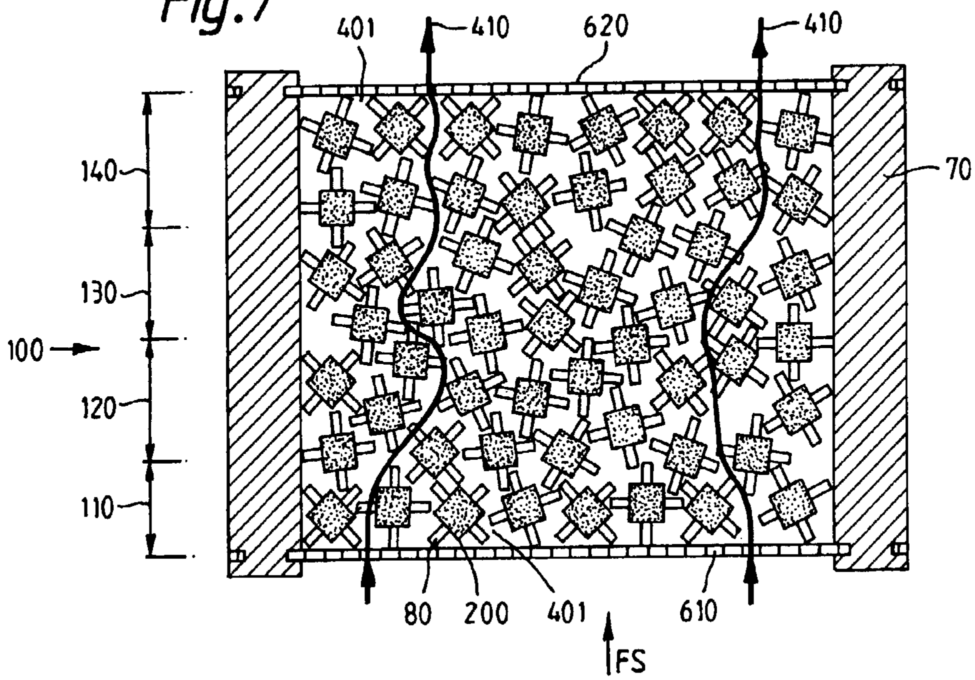

Fig.8A

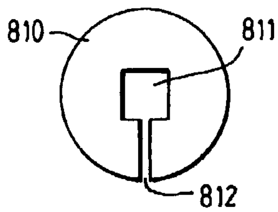

Fig.8B

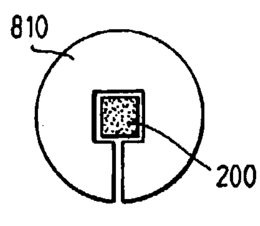

Fig.8C